National Aeronautics and Space Administration

Flight Processor Virtualization

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9/11/2013

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Agenda

- Introduction to Virtualization
- Benefits of Virtualization for Satellite Data Systems
- Summary of Research and Development
- Future Plans and Related Work

Introduction to Virtualization

- Hardware virtualization allows one or more virtual computer systems, or ***Virtual Machines (VM)***, to run on a single physical computer system
- Virtualization is accomplished using a small control program known as a ***Hypervisor***
- There are several different types of hypervisors:
  - **Full Virtualization** - Simulates a complete hardware platform often using special instructions in the CPU. Guest operating systems can run unmodified
  - **Paravirtualization** – A partial simulated hardware platform that requires a modified guest operating system to run. Can be more efficient than full virtualization
  - **Time/Space Partitioned** – Divides the hardware resources into strictly controlled partitions. Focus is in safety critical and secure applications

Introduction to Virtualization

Typical Virtualization Applications

- Servers and Data Centers
  - Virtualization powers the “Cloud”
  - Used to prevent physical “server sprawl”
- Desktop Systems
  - Allows desktop users to run multiple OS environments
  - VMWare, Virtualbox, Linux KVM, etc

- Mobile Systems
  - Used to partition a mobile device into distinct “work” and “home” environments for security and data integrity
- Safety critical embedded systems
  - Orion Crew Exploration Vehicle
  - F35-Joint Strike Fighter
  - FAA/Commercial Avionics programs

A Survey of Embedded Hypervisors

Product	Type	CPU Archs	Open Source?	Web Address
Sysgo PikeOS	Partitioned / Paravirtualization	ARM, LEON, PPC, X86	No	http://www.sysgo.com
Wind River Hypervisor	Full Virtualization	ARM, PPC, X86, MIPS	No	http://www.windriver.com
LynxOS-SE	Partitioned	X86, PPC, ARM	No	http://www.lynuxworks.com
Greenhils Integrity Multivisor	Full Virtualization	X86, PPC, ARM	No	http://www.ghs.com
CODEZERO embedded hypervisor	Full Virtualization	ARM v7	Yes	http://dev.b-labs.com
XtratuM embedded hypervisor	Paravirtualization	X86, LEON, ARM	Yes	http://www.xtratum.org
POK Separation Kernel	Partitioned	X86, PPC	Yes	http://pok.safety-critical.net
Xen ARM Hypervisor	Paravirtualization	ARM	Yes	http://www.xenproject.org

Benefits of Virtualization for Satellite Data Systems

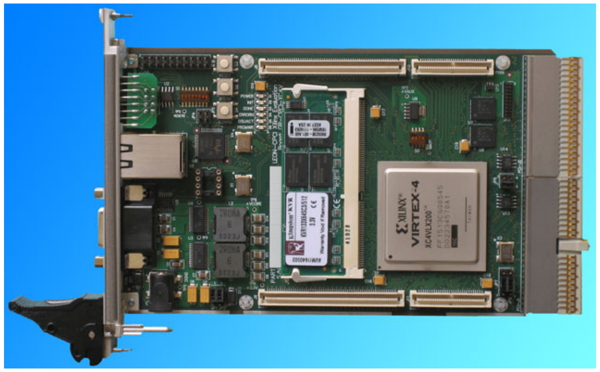
- Increase the ability to host on-board science data processing software *(FY12 IRAD)*
- Consolidate multiple physical processors for a reduction of Size, Weight, and Power (SWaP) *(FY13 IRAD)*
- Provide enhanced fault isolation between flight software subsystems *(FY13 IRAD)*
- Increase portability of flight software to new flight platforms including multi-core systems
- Increase security on flight systems

Virtualization is an enabling technology for developing innovative solutions for NASA missions

Summary of Research and Development

Research Platform

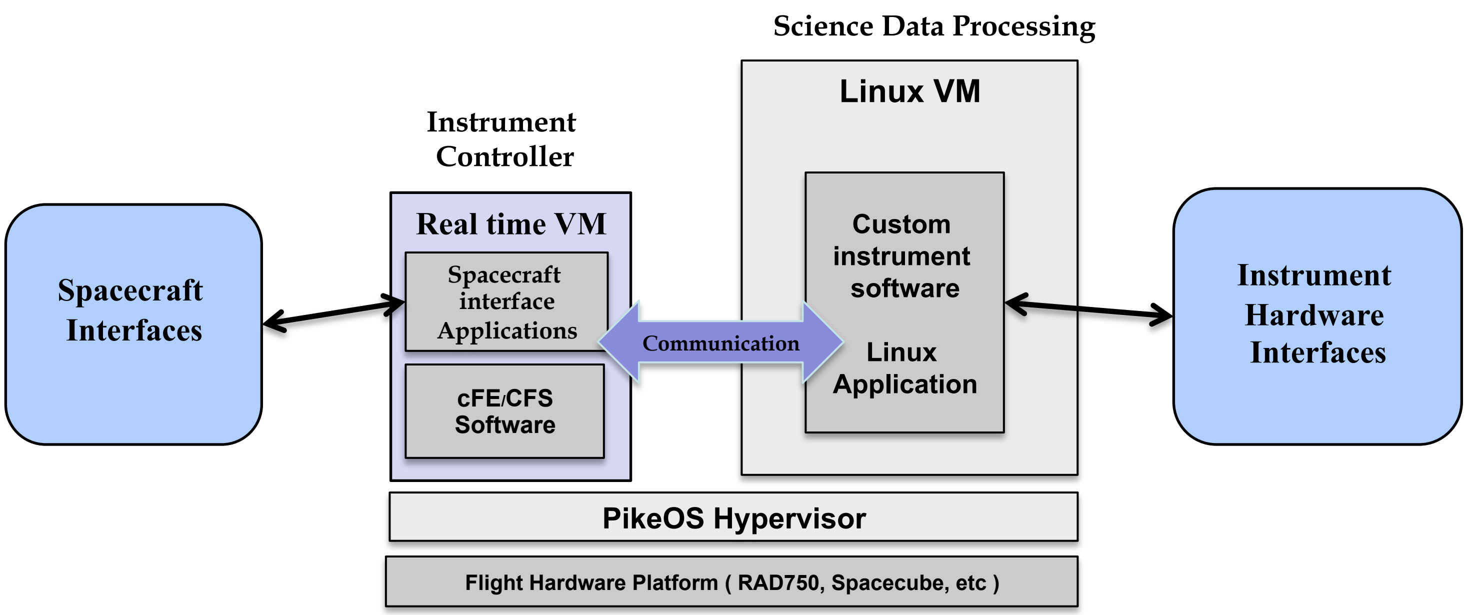
- **Hardware**
  - Gaisler/Aeroflex LEON3 Processor Card
    - 128MB RAM
    - 60 Mhz LEON3 CPU
    - Ethernet, UART
    - Compact PCI Bus
- **Hypervisor**
  - Sysgo PikeOS Real Time Embedded Hypervisor
  - A micro kernel that provides strict time and resource partitioning
  - Offers Linux, legacy RTOS, RTEMS, POSIX, and ARINC653 personalities
  - DO-178B and MILS certifications
- **Embedded Linux**
  - Sysgo ElinOS embedded linux
  - Paravirtualized guest for PikeOS
- **Flight Software**
  - GSFC's Operating System Abstraction Layer
  - GSFC's Core Flight Executive



Summary of Research and Development

FY2012 IRAD – Flight Hardware Virtualization for Science Data Processing

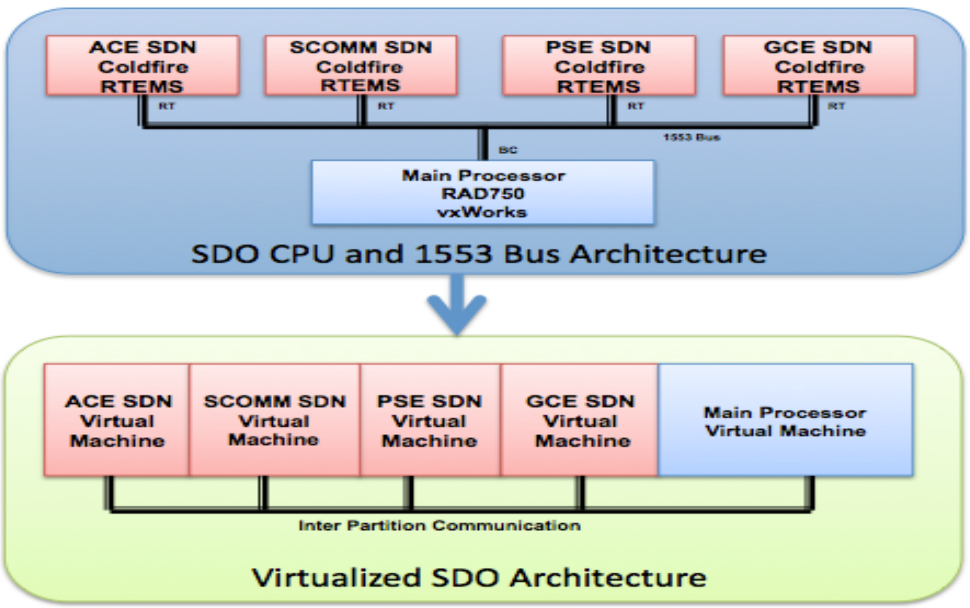
- Prototyped embedded hypervisor system consisting of a LEON3 processor board, a real time Core Flight Executive Virtual Machine, and a Science Data processing Linux Virtual Machine.
- Demonstrated that standard Linux software can run in a partition and has no effects on a real time control partition
- Linux VM can crash or reboot without affecting command and telemetry flow



Summary of Research and Development

FY2013 IRAD – Flight Processor Virtualization for Size, Weight, and Power Reduction

- Modeled the flight software from 5 Solar Dynamics Observatory (SDO) flight processors onto a single LEON3 CPU running an embedded hypervisor
- Each SDO processor runs in its own virtual machine/partition
- Replaced the 1553 communication bus with a software inter-partition communication mechanism provided by the operating system
- Note: Virtualization does not eliminate the need for redundant processors or data busses

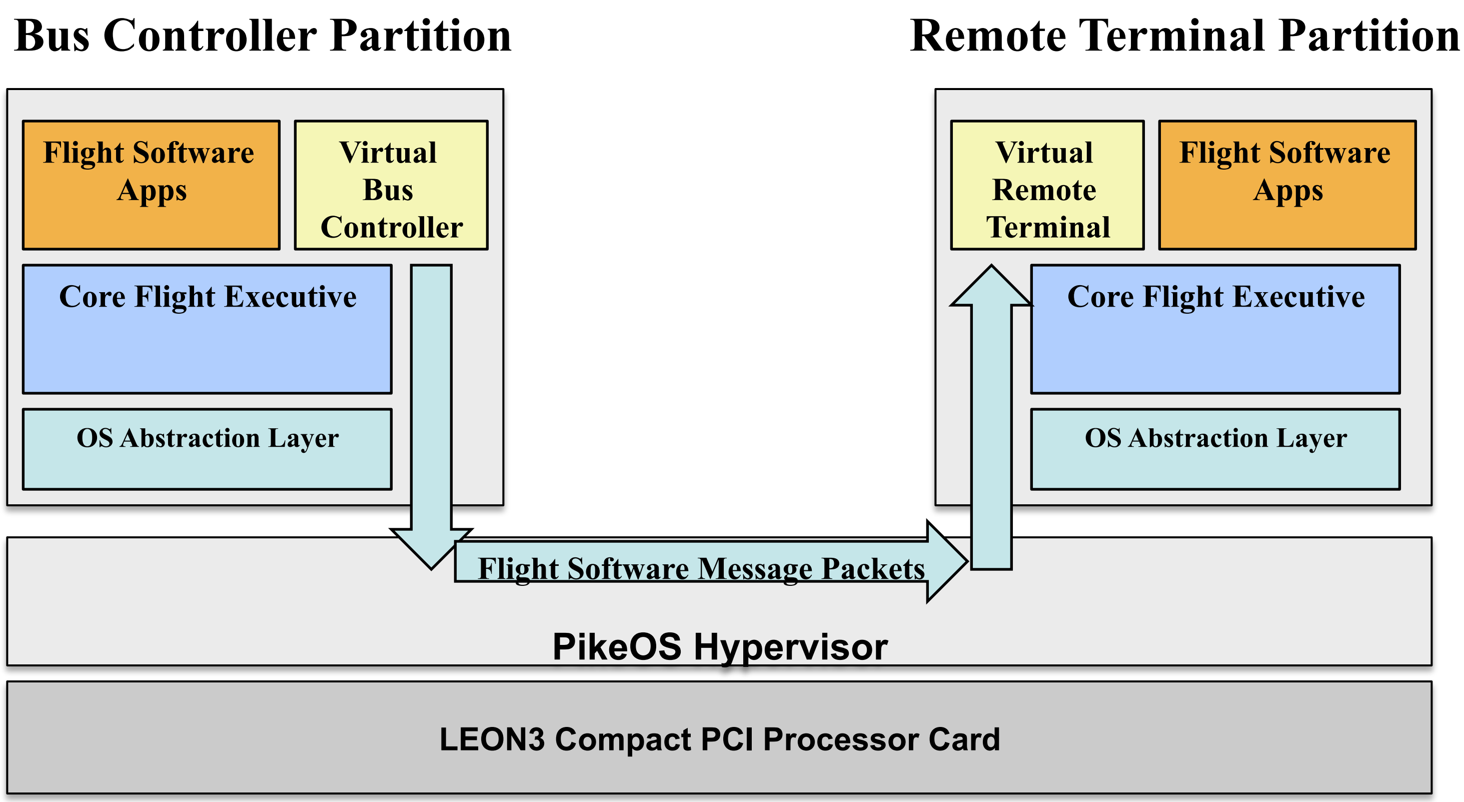


About SDO:

- SDO consists of ten separate processors connected on dual redundant 1553 busses.
- Hot/Cold CPUs include:
  - C&DH/GNC RAD750
  - 4 Coldfire SDNs
- Each CPU has relatively low CPU utilization (~20%)
- Each SDN processor uses ~ 4.75 watts giving a potential savings of 19 watts

Summary of Research and Development

FY2013 IRAD – Software Stack and Bus Controller to Remote Terminal Communication



Summary of Research and Development

FY2013 IRAD – Flight Processor Virtualization for Size, Weight, and Power Reduction

- Successful demonstrations of the virtualized SDO platform will include:
  - The ability to boot all flight processors in virtual machines
  - The ability to reboot virtual processors on an individual basis, especially the ACE/safe-hold computer
  - The ability to provide real time inter-processor communication
  - The demonstration of fault tolerance by showing that exceptions in individual virtual machines do not affect the other virtual machines
  - The ability to measure CPU utilization on each partition

Future Plans and Related Work

- **Future Plans**
  - The IRAD efforts have produced Operating System Abstraction Layer (OSAL) and Core Flight Executive (cFE) ports for the PikeOS hypervisor
    - These ports should be finalized and configured in the repositories for customers
  - The PikeOS/OSAL/cFE Platform could be ported to the Code 561 LEON3 Single Board Computer and offered as a solution for customers
- **Related Work**
  - Johnson Space Center / Advanced Exploration Systems is working on a port of the OSAL, and cFE to an ARINC653 partitioned system for use in human-rated applications
    - This effort is very similar to the port done by these IRADs
    - It should be possible to run the JSC Core Flight Executive on our LEON3/PikeOS platform

- Virtualized/partitioned systems will be well supported for future GSFC missions – enabling the benefits/capabilities described in this presentation